DOCTOR
OF
PHILOSOPHY

EFFICIENT NEARLY ORTHOGONAL AND SPACE-FILLING EXPERIMENTAL DESIGNS FOR HIGH-DIMENSIONAL COMPLEX MODELS

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The Department of Defense uses complex high-dimensional simulation models as an important tool in its decision-making process. To improve our ability to efficiently explore larger subspaces of these models, this dissertation develops a set of experimental designs for searching over as many as 22 variables in as few as 129 runs. These new designs combine orthogonal Latin hypercubes and uniform designs to create designs having near orthogonality and excellent space-filling properties. Multiple measures are used to assess the quality of candidate designs and to identify the best one. For situations in which more than the minimum number of required runs are available, the designs can be permuted and appended to create additional design points that improve upon the design's orthogonality and space-filling.

The designs are used to explore two surfaces. For a known 11 dimensional stochastic response function containing nonlinear and interaction terms, it is shown that the near orthogonal Latin hypercube is substantially better than the orthogonal Latin hypercube in estimating model coefficients. The other exploration uses the agent-based simulation MANA to analyze 22 variables in a complex military peace enforcement operation. The need for maintaining the initiative and speed of execution during these peace enforcement operations is identified.

KEYWORDS: Experimental Design, Latin Hypercube, Uniform Design, Agent-Based Simulation, Military Peace Enforcement Operations

VARIATIONAL RETRIEVAL OF EASTERN PACIFIC ATMOSPHERIC BOUNDARY LAYER PARAMETERS USING ATOVS WITH THE COAMPS™ MESOSCALE FORECAST SYSTEM

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A one-dimensional variational (1DVAR) retrieval scheme is used to investigate the ability of the Advanced TIROS Operational Vertical Sounder (ATOVS) to contribute information to a mesoscale NWP system within the summertime Eastern Pacific (EPAC) environment. This system is the Coupled Ocean – Atmosphere Mesoscale Prediction System (COAMPS™) and the Naval Research Laboratory (NRL) Atmospheric Variational Data Assimilation System (NAVDAS). Analyses of information content and retrieval performance show that, when treated optimally, significant humidity and temperature information can be derived from ATOVS retrievals within the clear and cloudy sky summertime EPAC environment. A

study of retrieval error sensitivity to representative background state vector elements and associated errors was also conducted to establish the *a priori* elements critical for successful 1DVAR retrievals. 1DVAR profile temperature and humidity retrievals were generated using both simulated and actual ATOVS observations constrained by the COAMPS short-term forecasts and a synoptically relevant background error covariance matrix. The time period of interest coincides with the DYCOMS Phase II field study. The 1DVAR retrieval results indicate that ATOVS observations can provide information that, when used in concert with a COAMPS background field, reduce the retrieval error and adjust the retrieval within the shallow boundary layer toward the designated "true" profile.

KEYWORDS: Variational Satellite Retrieval, 1DVAR, COAMPS, NAVDAS, ATOVS, HIRS/3, AMSU-A, AMSU-B, DYCOMS II, Information Content, Non-linear Optimal Estimation Theory, Mesoscale Satellite Data Assimilation, Marine Atmospheric Boundary Layer, MABL

RANDOMIZED ENSEMBLE METHODS FOR CLASSIFICATION TREES

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Two methods of constructing ensembles of classifiers are proposed. One method directly injects randomness into classification tree algorithms by choosing a split randomly at each node with probabilities proportional to the measure of goodness for a split. This method is combined with a stopping rule which uses permutation of the outputs. The other method perturbs the output and constructs a classifier using the perturbed data. In both methods, the final classifier is given by an unweighted vote of the individual classifiers. These methods are compared with bagging, Adaboost, and random forests on thirteen commonly used data sets. The results show that our methods perform better than bagging, and comparably to Adaboost and random forests on average.

Additional computation shows that our perturbation method could improve its performance by perturbing both the inputs and with the outputs, and combining a sufficiently large number of trees. Plots of strength and correlation show an interesting relationship. Combining sampling subsets of the training set with proposed methods is also explored. The results of a few trials show that the performance of our proposed methods could be improved by combining sampling subsets of the training set.

KEYWORDS: Classification, Ensemble Methods

ENHANCEMENTS AND EXTENSIONS OF FORMAL MODELS FOR RISK ASSESSMENT IN SOFTWARE PROJECTS

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The Modified Risk Model is a macro model developed to aid program managers in effectively planning the required effort to deliver software products. The model projects the probability of completing a software project, subject to the available resources supplied by management. This approach to software project risk management is unique because the model's input parameters are derived. Subjective variables are not part

of the model. Different program managers would derive the same projections on the same software project. Risk management is most effective in impacting the project's success if project risks are identified and mitigated early in the software lifecycle. The Modified Risk Model was developed specifically for this purpose. Additionally, the Modified Risk Model is versatile enough to be adapted to any software development activity. Validation of the model occurs in approximately 2,000 software projects. During these preliminary experiments, the Modified Risk Model out-performed the macro models of Basic COCOMO and the Simplified Software Equation.

KEYWORDS: Risk Assessment, Formal Models, Software Estimation Models, Software Metrics, Project Management, Monte Carlo Simulation

AN AGENT BASED ARCHITECTURE FOR GENERATING INTERACTIVE STORIES

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The Department of Defense relies on modeling and simulation for a variety of purposes, including joint exercise training, developing and evaluating doctrine and tactics, and studying weapon system effectiveness. Advances in technology have made the achievement of technically and visually accurate simulations possible, but little has been done to present realistic scenarios while supporting user interaction. This dissertation describes a multi-agent interactive simulation engine for generating interactive scenarios or stories. A general-purpose multi-agent system simulation architecture called a Connector-based Multi-Agent System (CMAS) is developed and presented, along with a software agent communication and coordination mechanism. In this architecture, stories are generated through discovery as a by-product of agent interactions, rather than being fixed in advance. The ensuing story adapts to the user's interventions and is closely aligned to the goals of the agents. The multi-agent system design of the story engine has resulted in a data-driven simulation engine, which is domain independent and highly scalable.

The story engine is fielded as the underlying simulation engine behind the U.S. Army's *America's Army: Soldiers* project. The instantiation of the story engine as it applies to *Soldiers* is presented. As a component of *Soldiers*, the story engine is an integral module in an interactive story generation system.

KEYWORDS: Multi-Agent System, Multi-Agent Simulation, Interactive Simulation, Scenario-Based Training, Interactive Stories, Interactive Narrative

MEASUREMENTS AND OBSERVATIONS OF INTERFACIAL CREEP IN ENGINEERING SYSTEMS

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In many applications, large shear stresses develop at interfaces between dissimilar materials during thermo-mechanical excursions, when there is a significant difference in the coefficient of thermal expansion between them. When the system is elevated to a high homologous temperature for one of the adjoining materials, the applied shear stress may allow the interface to slide without debonding by a diffusionally

accommodated mechanism, thereby allowing relative dimensional changes to occur. The purpose of this dissertation is to establish the kinetics and mechanism of interfacial creep and to evaluate its impact on thin film structures used in microelectronic devices. Studies of interfacial creep kinetics were based on diffusion-bonded interfaces in Si-Al-Si sandwich specimens, which were loaded in a double-shear configuration with the interfaces being subjected to a nominal shear stress during creep tests. In some tests, a normal stress was superimposed on the applied shear stress to articulate the role of the normal stresses, which are often present at interfaces. It was found that in agreement with previous results, the interface crept by interfacial diffusion-controlled diffusional creep driven by the applied shear stress, with the applied normal compressive stress resulting in a threshold behavior below which no creep occurred. The effect of interfacial roughness was also evaluated and the results showed that the interfacial creep rate decreased for specimens with larger interfacial roughness. The impact of interfacial creep in interconnect structures in microelectronic devices were observed via atomic force microscopy for (a) stand-alone thin film Cu lines on Si and (b) Cu lines embedded in a low k dielectric on Si substrates. Following thermal cycling, changes were observed in the in-plane Cu line dimensions, as well as the out-of plane step height between Cu and dielectric in single layer structures. Both effects were attributed to interfacial diffusion-controlled interface sliding.

KEYWORDS: Interface Sliding, Interfacial Creep, Al-Si Interface, Activation Energy, Amorphous, Diffusion Bonding, Interconnect Structures